NASA RFID Applications

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Roadmap

- Inventory management in space
  - Apollo, Space Shuttle, Space Station
- Potential RFID uses in a remote human outpost
- Passive, wireless sensors in NASA applications
- E-textiles for wireless and RFID
Apollo Inventory Concept

Top level stowage drawing showing Command Module stowage layout

Sample table of items contained in modular container locations – used to layout vehicle and train crews on item locations

(Reference Apollo Experience Report: Crew Station Integration - Stowage & the Support Team Concept, 1972)
Shuttle Inventory Concept  
(non-Transfer to ISS)

- Crew is provided hard copy of items listed by location (no part numbers, serial numbers, etc., provided)
- Crew also has the ability to look items up in laptop database, but often times calls down to Mission Control if item locations are needed

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STS-109 MIDDECK STOWAGE

<table>
<thead>
<tr>
<th>FORWARD LOCKERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF14E</td>
</tr>
<tr>
<td>Food, Menu</td>
</tr>
<tr>
<td>FRED</td>
</tr>
<tr>
<td>MF14G</td>
</tr>
<tr>
<td>Clothing, CDR</td>
</tr>
<tr>
<td>MF14H</td>
</tr>
<tr>
<td>Bags</td>
</tr>
<tr>
<td>Helmet Stowage (2)</td>
</tr>
<tr>
<td>Inflight Stowage, Restraint (10)</td>
</tr>
<tr>
<td>Jettison Stowage (10)</td>
</tr>
<tr>
<td>Bungee, Adjustable (7)</td>
</tr>
<tr>
<td>Canister, WCS (Coffee Can)</td>
</tr>
<tr>
<td>Covers</td>
</tr>
<tr>
<td>HUD (4)</td>
</tr>
<tr>
<td>Parachutes (7)</td>
</tr>
<tr>
<td>Hoses</td>
</tr>
<tr>
<td>Personal Hygiene</td>
</tr>
<tr>
<td>WCS Canister</td>
</tr>
</tbody>
</table>

| (Cont) |
| Kits   |
| Comm   |
| Cables |
| Comm, 4 ft |
| Comm, 14 ft |
| Mic, Handheld (3) |
| VHS (2) |
| Saliva |
| Mirror (2) |
| O2 Bleed Orifice |
| Pip Pin (12) |
| Pip Pin, Escape Pole (Spare) |
| Switch Guard, Computer |
| Tape   |
| Gray, 1 in |
| Gray, 2 in |
| Ziploc, 8 in (20) |
| Ziploc, 12 in (8) |

| MF14K |
| Air Bottles |
| Breaker Bar, 3/8 in |
| Breakout Box |
| Fire, Waste Water Dump |
| Kit, RMS D&C |
| Turnbuckles |

| MF14M |
| FDF | Bag, WVS |

| MF14O |
| Food, Menu |
| Food, Menu |

| MF28E |
| Food, Menu |
| Food, Menu |

| MF28G |
| Clothing, PLT |
| Clothing, PLT |

(Reference STS-109 FDF Flight Supplement)
The Inventory Management System (IMS) is used to track items on the ISS
- Handheld barcode reader is used by the crew for quick on-site updates
  - Data from the barcode reader may be passed to the onboard IMS database by RF or serial hardline connection to the laptop
  - Expedition 15 will use the new PDAs to access IMS and perform barcode scans.
- IMS software application is used for complex updates
  - Manual crew entries into onboard database on laptop
  - Flight control team entries into ground database
- Databases are synchronized by uplinking and downlinking “Delta Files”
RFID – Lunar Outpost

• High probability applications
  – Inventory management
    • Crew supplies (e.g., personal items, office supplies, clothing)
    • Food, medicine
  – Real-Time Localization
    • EVA tools, equipment
  – Monitoring/verifying inter-habitat supply transfers
  – “Boneyard” inventory
    • Real-time access to surplus parts

• Smart tag and other potential applications
  – Monitor tool exposure limits and provide warnings (e.g., temperature extremes, shocks)
  – Storage of calibration information on sensors, LRUs
  – Passive tag tracking

Example: passive COTS tag with 64 bit ID code, temperature and range telemetry
Passive, Wireless Sensors

- Where possible, no-batteries
- Reduces wire, crew time, certification costs, weight, power, and size
- Numerous conceivable applications

64-bit SAW-based COTS RFID tag

AirGATE Technologies / CTR tag

8-bit SAW-based COTS RFID tag

Interrogator

Potential applications for wireless ice sensor system

Passive sensor arrays (enlarged)

Ice sensor
• 70 MHz SAW-based sensors
  – G. Studor (JSC), R. Brocato (SNL), et al
• Key advantage: integrates existing sensor types into passive, wireless system
• System discussed in earlier presentation
• Requires efficient, miniaturized antennas
HF Antennas

- **Significant size reduction of the antenna**
  - Half-wave dipole ($0.5\lambda_0$, 2.14m)
  - Miniaturized spiral-loaded slot antenna & ground plane ($0.07\lambda_0 \times 0.11\lambda_0$, 0.3m x 0.46m)

- **Habitat walls are electrically conductive**
  - Cannot use wire antenna directly against conducting wall
  - Integration of miniaturized HF antenna with habitat walls
    - E-textile antennas
HF Passive Sensor Antennas

- Miniature Spiral-Loaded Slot Antenna

Prototype 4
(45.7cm x 30.5cm x 0.32cm)
Coupling between two 70MHz antennas
- Received power levels at different locations in the mockup
- Model effects of blockage with equipment in habitat module
Effects of Wavelength on SNR

If we fix the interrogator antenna gain \((G_t, G_r)\):

\[
SNR = \left(\frac{\lambda}{4\pi}\right)^4 \frac{1}{R_r^2 R_t^2} \frac{P_t G_t G_r G_{tag}^2}{kTB F_n L_{tag}^2}
\]

If we fix the interrogator antenna area \((A_t, A_r)\):

\[
SNR = \left(\frac{1}{4\pi}\right)^2 \frac{1}{R_r^2 R_t^2} \frac{P_t A_t A_r G_{tag}^2}{kTB F_n L_{tag}^2}
\]

Fixing the area and increasing frequency may require some type of antenna pointing.
RF Collision Avoidance Methods

- Spatial diversity through adaptive digital beamforming

- Chamber A: Vacuum and Thermal Cycle Testing of Flight Hardware
  - Objective: replace wired thermal and pressure sensors with wireless sensors
    - Reduces setup time between vehicle configuration changes
  - Stage: feasibility assessment
  - Thermal limit cold side: 20K
  - Applications for vibration and acoustic facilities are also being explored

Approximate dimensions: 
- Diameter: 45'
- Height: 80'

NASAA
Environmental Facility Wireless Sensors

- Adaptive interrogation of wireless temperature and pressure sensors
- Goals: $T_{\text{low}} = 20\text{K}$; 1000s of T-sensors; 100s of P-sensors

JSC Chamber A
(Vacuum & Thermal Cycle)
Antenna System Approach

- No active sensor system elements inside the chamber
- Adaptive digital beamforming offers many design degrees of freedom
  - The system can learn optimal channel weighting coefficients prior to commencement of tests
- Interrogator aperture:
  - Small transmit aperture - attempt to minimize transmit directivity
  - Large receive aperture – high directivity for spatial diversity
- Additional collision avoidance obtained through:
  - polarization division and code division
Small Transmit Aperture for Broad Illumination

Transmitter / receiver
Large Receive Aperture for Spatial Diversity

- Digital samples on each receive element
- Beams are formed digitally
  - number of beams limited only by external processors
- Ideally, all tags within transmit beam are read
Example of Spatial Diversity: Schelkunoff array

- Chamber Simulation
- Tag 5

8 Element Schelkunoff Array
- Patch width = 4.14 cm
- Substrate thickness = .445 cm
- Element spacing: \( d = 0.62 \lambda \)
• Characterizing digital beamforming array in anechoic environment
  – Extracting signal from noise through digital summation

• Test in Chamber A by Summer 2007
E-Textiles at NASA

- Conductive fabric circuits and antennas can be manufactured in an art-to-part process (e.g., see NASA MSC-24332, DARPA efforts)

- Performance can be indistinguishable from conventional counterparts for many circuits, including RF/microwave circuits and antennas
  - Equiangular spiral
  - Microstrip patch antennas
  - Quadrature hybrid coupler
Symposium for Space Applications of Wireless & RFID 2007

May 8-9, 2007
Houston, TX

http://www.ghg.net/ieeegbs/swirf2007/